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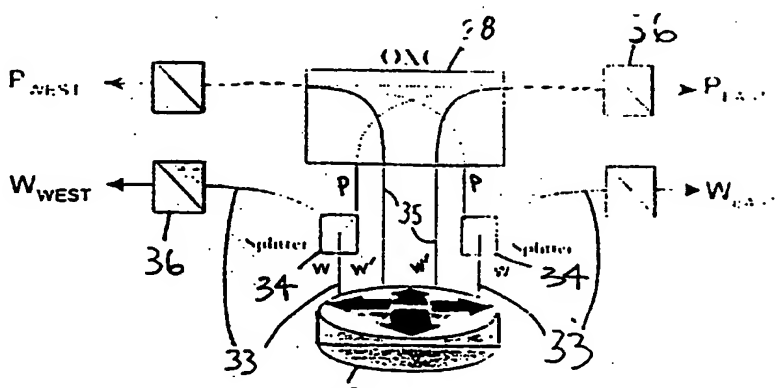

NODE 38

(57) Abstract: A communication network for transmitting and restoring an optical signal in a data optimized optical ring is presented. The optical ring includes nodes, each containing an optical cross connect switching fabric that is coupled to a data switch. The optical cross connect switching fabric and the data switch may further be coupled to a short reach side of at least one wavelength translation device and a long reach side of the wavelength translation device is coupled to a dense wave division multiplex coupler. Each node includes at least one protect channel and at least one working channel for transporting the optical signal. The data optimized optical ring is adapted to carry extra optical signals, which are unprotected and un-restored low priority signals. By concurrently transporting and processing the extra optical signals and the regular optical signals, the network's capacity is increased resulting in greater traffic utilization.

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COMMUNICATION NETWORK FOR TRANSMITTING AND RESTORING AN OPTICAL SIGNAL

Cross Reference to Related Applications

This application is related to U.S. Patent Application Attorney Docket No. 10210RR (22171.127), filed on even date herewith, entitled SYSTEM AND METHOD FOR TRANSMITTING AND RESTORING AN OPTICAL SIGNAL, assigned to the assignee of the present application, and hereby incorporated by reference herein.

Background

This application relates generally to optical communication systems and, more particularly, to a communication network for transmitting and restoring optical signals.

A conventional method for transmitting optical signals is disclosed in U.S. Patent No. 5,933,258 by Flanagan et al. This conventional method utilizes terminals, at a node, that multiplex fine granularity signals (such as STM-4, OC-12, etc.) from SONET, SDH, or other transport protocols, into coarse granularity signals (such as STM-64, OC-192, etc.) that are forwarded to an optical cross connect (OXC) switch. The signals are then transmitted to a terminal at another node in the optical communication system. In order for the signal to reach the terminal, it may have to be amplified or regenerated. The regenerator converts optical signals into the electrical domain, performs various actions on the signals, such as re-synchronizing the signal with a stratum clock, and then reconverts and re-amplifies the signals back into the optical domain. Furthermore, wavelength detectors are utilized at the regenerator to ensure the correct signal is always being transmitted for a particular route.

Such prior art approaches have a number of limitations. One such limitation is that a wavelength detection scheme must be implemented at all regeneration sites to ensure a proper reception of protection signals. The proper reception of the protection signals is needed to ensure that wavelength contingency (which is caused when a wavelength travels in an incorrect direction around an optical ring, from, for example, a link cut) does not occur. Additionally, optical signals incur significant power loss as they transit through the optical switching fabric at transit nodes or origination and destination

nodes. Further, as data centric switching products (such as routers and Asynchronous Transfer Mode (ATM) switches) emerge, SONET interfaces from such products will increase in speed (e.g., from OC-48 to OC-192). This will lead to an inefficient handling of the optical signal traffic because the conventional interfaces (or tributary access) on SONET/SDH multiplexing equipment typically accept only low speed traffic (such as STM-1, OC-12, etc.). This traffic must then be multiplexed to create a bit rate high enough to justify long distance optical transmission, thereby introducing a further limitation.

Another limitation of the prior art regards the fact that the conventional optical ring must be balanced by including the same number of working channels and protection channels between each node. Certain nodes, however, may not need as many working channels and protection channels as other nodes might because, for example, the traffic between these nodes may not be as heavy as the traffic between the other nodes. As such, the conventional optical ring may utilize a higher number of terminals than needed increasing the cost and complexity of the system.

To reduce or eliminate these limitations and design complexities, U.S. Patent Application Attorney Docket No. 10210RR (22171.127), entitled System and Method for Transmitting and Restoring an Optical Signal, discloses an improved communication network for transmitting and restoring an optical signal in an optical ring. The optical ring comprises a plurality of nodes, each node containing an optical cross connect switching fabric coupled to a data switch. The optical cross connect switching fabric and the data switch are coupled to a short reach side of a wavelength translation device. A long reach side of the wavelength translation device is coupled to a dense wave division multiplex (DWDM) coupler. The optical cross connect switching fabric and the data switch include a protect channel and a working channel for transporting the optical signal. The wavelength translation device receives the optical signal at a high speed rate, where the optical signal is a short reach optical signal and originates from a high speed interface on the data switch. The wavelength translation device then maps the short reach optical signal into a long reach DWDM optical signal at the high speed rate and forwards, via the DWDM coupler, the long reach optical signal to an adjacent DWDM coupler

located at an adjacent node. If a link failure occurs and has not recovered, and the protect channel is not available, optical cross connect switching fabrics at adjacent nodes on each side of the failed link switch the optical signal to a diversely routed protect port. An optical pass through of the switched optical signal between any transit nodes in the optical ring is then configured resulting in a restoration path for the working channel.

While this improved communication network has many advantages, especially in regard to a data centric traffic environment, it does not address the scenario in which extra optical signals, which are unprotected and un-restored low priority signals, may be transported throughout the network. In such a scenario, the network's capacity is increased as the regular optical signals and the extra optical signals may be concurrently transported and processed, resulting in greater traffic utilization. Therefore, a data optimized optical ring that can transport these extra optical signals is desired.

Summary

In response to these and other limitations, provided herein is a unique system and method for transmitting and restoring optical signals in an optical ring. The optical ring includes nodes, each containing an optical cross connect switching fabric that is coupled to a data switch. The optical cross connect switching fabric and the data switch are further coupled to a short reach side of at least one wavelength translation device and a long reach side of the wavelength translation device is coupled to a dense wave division multiplex coupler. Each node includes at least one protect channel and at least one working channel for transporting the optical signal.

In one embodiment, a splitter receives short reach optical signals at a high speed rate via a working path, where the optical signals originate from at least one working access port on the data switch and where the splitter is coupled between the data switch and both the optical cross connect switching fabric and the wavelength translation device.

In some embodiments, the splitter forwards the optical signals to the short reach side of the wavelength translation device via the working channel on a primary working path.

In some embodiments, if extra optical signals are available, the optical cross connect switching fabric receives the extra optical signals via a secondary working path and/or transports the extra optical signals via an unused protect path.

In some embodiments, if an equipment failure occurs, the optical cross connect switching fabric disconnects the secondary working path transporting the extra optical signals, deletes from the protect path, the extra optical signals, and transports the working optical signals via the protect path after they have been forwarded by the splitter.

In some embodiments, if a line failure occurs, the optical cross connect switching fabric disconnects the secondary working path transporting the extra optical signals, deletes from a diverse protect path, the extra optical signals, and transports the working optical signals via the protect path after they have been forwarded by the splitter.

In some embodiments, the short reach side of the wavelength translation device receives the optical signals at a high speed rate via the working channel on a working path, where the optical signals are short reach optical signals and originate from at least one 1+1 working access port on the data switch.

In some embodiments, if extra optical signals are available, the optical cross connect switching fabric receives the extra optical signals via at least one 1+1 protect access port and/or via at least one working access port on the data switch, and transports the extra optical signals via a protect path.

In some embodiments, if an equipment failure occurs, the optical cross connect switching fabric disconnects the at least one working access port transporting the extra optical signals, deletes the extra optical signals from the protect path, and transports the working optical signals via the protect path after the working optical signals have been forwarded by the 1+1 protect access port.

In some embodiments, if a line failure occurs, the optical cross connect switching fabric disconnects the at least one working access port transporting the extra optical signals, deletes the extra optical signals from a diverse protect path, and transports the working optical signals via the diverse protect path after the working optical signals have been forwarded by the 1+1 protect access port.

These advantages, as well as others which will become apparent, are described in greater detail with respect to the drawings and the following disclosure.

Brief Description of the Drawings

Fig. 1 is a diagrammatic view of a data centric optical system.

Fig.2 is a diagrammatic view of an equipment failure in the data centric optical system.

Fig.3 is a diagrammatic view of a line failure in the data centric optical system.

Fig. 4 is a diagrammatic view of a node that includes a splitter in an optical system of the present invention.

Fig. 5 is a diagrammatic view of an equipment failure in the optical system that includes a splitter of the present invention.

Fig. 6 is a diagrammatic view of a line failure in the optical system that includes a splitter of the present invention.

Fig. 7 is a diagrammatic view of a node that includes 1+1 access ports of the present invention.

Fig. 8 is a diagrammatic view of an equipment failure in the optical system that includes 1+1 access ports of the present invention.

Fig. 9 is a diagrammatic view of a line failure in the optical system that includes 1+1 access ports of the present invention.

Fig. 10 is a diagrammatic view of a computer of the present invention.

Fig. 11 is a flow chart of a method for transmitting and restoring an optical signal failure in the optical system that includes a splitter of the present invention.

Fig. 12 is a flow chart of a method for transmitting and restoring an optical signal in the optical system that includes 1+1 access ports of the present invention.

Detailed Description

Fig. 1 depicts an optical communication system or ring 10 for implementing one embodiment of the present invention. The optical ring 10 includes nodes 12-16, each containing an optical cross connect switching fabric (or OXC switch) 18 that is coupled to a data switch 20. The optical cross connect switching fabric 18 and the data switch 20 are further coupled to a short reach side of at least one

wavelength translation device (or transponder) 26 and a long reach side of the wavelength translation device is coupled to a dense wave division multiplex (DWDM) coupler 22. The optical cross connect switching fabric 18 and the data switch 20 include at least one protect (P) channel (or port) and at least one working (W) channel (or port) for transporting the optical signal (also known as the primary working channel).

The data switch 20 from, for example node 12, is able to receive short reach optical signals at a high speed rate via its high speed 1+1 (1 working and 1 protect) ports. These signals are then forwarded to the transponder 26 which maps the short reach optical signal (of, for example, 1310 nm, on the short reach side of the transponder) into a long reach transport and dense wave division multiplex (DWDM) ready signal (of, for example, 1550 nm, on the long reach side of the transponder). The transponder 26 then forwards the long reach optical signal to the DWDM coupler 22. The DWDM coupler 22 can receive various high speed signals from a number of other optical rings (not shown) and combines the signals on one fiber (such as the working channel). The signal(s) may then be sent to an optical amplifier 24 which, if needed, amplifies the optical signal. The long reach optical signal is then received by another optical amplifier 24 and/or another DWDM coupler 22 in another node, such as node 14. Additionally, the signal(s) may be sent to a regenerator (not shown) which, if needed, regenerates or improves the quality of the optical signal.

Unlike prior art optical rings, the use of terminals are no longer needed because the optical ring 10 interfaces directly with the high speed data switch 20 ports. As such, the optical signals may be directly and more efficiently transmitted at very high speeds (up to, for example, OC-192+) thereby omitting the need for having to multiplex, at the terminal, traffic of fine granularity signals into a coarse granularity signal.

Prior art optical rings are also economically less attractive when compared to a more data centric variation such as the optical communication system 10. By placing OXCs 18 on the short reach side of the transponders 26, wavelength contingency and wavelength detection are eliminated at regeneration sites because the correct signal is always being transmitted for a particular route. Thus,

wavelengths would always be traveling in the proper direction without having to utilize wavelength detectors from prior art optical rings. Therefore, the regeneration or optical amplification process (which converts and reconverts optical signals into the electrical domain) at nodes may be eliminated. Additionally, since the OXC switches 18 rely on the use of high speed (such as, STM-16, OC-48, OC-192+) interfaces, they do not require further time division multiplexing from traditional terminals. Furthermore, the impact of optical switching fabric loss is removed from the transmission link budget since only the protection traffic is terminated on the OXC 18.

The protect channel(s) operate in either a normal operation span switched setting or in a link failure alternate direction setting. Fig. 2 depicts the protection channel(s) from optical communication system 10 operating in a normal operation span switched setting. If equipment failure (such as a laser) was noted (in, for example, data switch 20 at node 14) or if a failure occurred on the link transporting the working channel (such as the working channel between node 14 and node 16), the traffic for these nodes would be rerouted via the protect channel of node 14. In this manner, the traffic is not degraded and reaches its intended destination. The OXC 18 then monitors, for example, the primary working signal to determine if the failure has recovered. If it has, the working channel is again utilized and the protect channel becomes available.

Fig. 3 depicts the protection channel(s) from the optical communication system 10 operating in a link failure alternate direction setting. If the entire link between node 12 and node 16 failed, the protection channel P(East) would not be available as described in Fig. 2. Thus, the OXCs 18 at adjacent nodes on each side of the failed link (nodes 12 and 16) would switch (or reroute) the optical signal(s) to the alternate diverse protect port P(West). An optical pass through of the switched optical signal is then configured between any transit nodes (such as node 18) in the optical ring to allow the signal(s) to flow directly between nodes 72 and 76. As such, a restoration path for the working signal is now available.

The OXCs 18 in nodes 12 and 16 monitor the primary working signal to determine if the link has recovered. If it has, the working channel is again utilized and the protect channel becomes available.

When this working traffic is rerouted it is done more efficiently than with prior art optical communication systems because the signals do not have to terminate on transit data switches (such as data switch 20 in node 14) as they are transmitted through the network. Additionally, because the signals are traveling at a high speed rate, they may not have to be amplified as they pass through a node.

As can be seen from the above description, the data centric optical communication system has many advantages. One limitation, however, is the inability of such a system to effectively transport extra optical signals.

Fig. 4 depicts a node 38 for placement in an optical communication system of the present invention. The node 38 includes an OXC 28 that is coupled to a data switch 32. The OXC 28 is further coupled to a short reach side of a wavelength translation device 36. A long reach side of the wavelength translation device 36 is coupled to a dense wave division multiplex coupler (not shown) which may be coupled, as described in the nodes 12-16 of Fig.'s 1-3, to an amplifier (not shown) and/or a regenerator (not shown). The node 38 further includes at least one working channel (W) for transporting the optical signals. The optical signals are sent from the data switch 32 to a splitter 34 at a high speed rate via the working channels on a working path 33. The splitter 34, which may be, for example, a 3dB splitter, utilizes roughly half of its power to optically split an incoming signal. Thus, the splitter 34 acts in a similar manner to a 1+1 port even though the optical signals were sent via a 0:1 (or working) access port on the data switch 32. The splitter 34 then forwards the optical signals to the short reach side of a wavelength translation device 36 via the working channel on the primary working path. The short reach signal is then converted to a long reach signal at the wavelength translation device 36 and transported to another node.

If extra optical signals (which are unprotected and un-restored low priority signals) are available, they may be sent by the data switch 32 to the OXC 28 on a secondary working channel (W') via a secondary working path 35. When the OXC 28 receives the extra optical signals, it transports them via a protect path, P(East) and/or P(West), wherein the protect path is unused.

Fig. 5 displays an optical communication system 40 in which an equipment failure and/or a link failure occurs that renders a working path (or link), such as the working path between nodes 42 and 44, inoperable. As such, working optical signals cannot be transported via that working path. In such a scenario, the OXC 28 disconnects the secondary working path 35 transporting the extra optical signals and deletes the remaining extra optical signals on the protect path. The splitter 34 then forwards, via a protect channel (P), the working optical signals and the OXC 28 transports these signals via the protect path P(North).

Fig. 6 displays the optical communication system 40 in which a line failure occurs between, for example, node 38 and node 44. As such, the working optical signals cannot be transported on the protect channel P(East) via that link. In such a scenario, the OXC 28 at node 38 disconnects the secondary working path 35 transporting the extra optical signals and deletes, from a diverse (alternate) protect path P(West), the extra optical signals. The diverse protect path P(West) is chosen by the OXCs 28 at adjacent nodes on each side of the failed link (nodes 38 and 44). The splitter 34 then forwards, via a protect channel (P), the working optical signals which are transported by the OXCs 38 and 44 via the diverse protect path P(West). The OXCs 28 in nodes 38 and 44 monitor the working optical signals to determine if the link has recovered. If it has, the primary (W) and secondary (W') working channels may again be utilized and the protect channel (P) is made available.

An optical pass through of the optical signals may be configured between any transit nodes (such as node 42) in the optical ring allowing the signals to flow directly between nodes 38 and 44. As such, a restoration path for the working signals is made available.

Fig. 7 depicts a node 58 for placement in an optical communication system of the present invention. The node 58 includes an OXC 48 that is coupled to a data switch 52. The data switch 52 may include a splitter (not shown) similar to the splitter discussed in Fig.'s 4-6. The OXC 48 and the data switch 52 are further coupled to a short reach side of at least one wavelength translation device 56. A long reach side of the wavelength translation device 56 is coupled to a dense wave division multiplex coupler (not shown) which may be

coupled, as described in the nodes 12-16 of Fig.'s 1-3, to an amplifier (not shown) and/or a regenerator (not shown). The node 58 further includes at least one working channel (W) and at least one protect channel (P) for transporting the optical signals.

The optical signals are sent at a high speed rate via the working channel on a working path 53 by the data switch 52 and received at the short reach side of the wavelength translation device 56. The optical signals are short reach optical signals and originate from at least one 1+1 working access port on the data switch 52. The short reach signal is then converted to a long reach signal at the wavelength translation device 56 and transported to another node.

If extra optical signals are available, they may be sent by the data switch 52 to the OXC 48 on a protect channel (P) via a 1+1 protect access port 55 and/or on a working (0:1) channel via a working access port 57. When the OXC 48 receives the extra optical signals, it transports them via a protect path, P(East) and/or P(West), wherein the protect path is unused.

Fig. 8 displays an optical communication system 60 in which an equipment failure and/or a link failure occurs that renders a working path (or link), such as the working path between nodes 62 and 64, inoperable. As such, working optical signals cannot be transported via that working path. In such a scenario, the OXC 48 disconnects the working access port 57 transporting the extra optical signals and deletes the remaining extra optical signals on the protect path. The 1+1 protect access port 55 then forwards, via the protect channel (P), the working optical signals and the OXC 48 transports these signals via the protect path P(North).

Fig. 9 displays the optical communication system 60 in which a line failure occurs between, for example, node 58 and node 64. As such, the working optical signals cannot be transported on the protect channel P(East) via that link. In such a scenario, the OXC 48 at node 58 disconnects the working access port 57 transporting the extra optical signals and deletes, from a diverse (alternate) protect path P(West), the extra optical signals. The diverse protect path P(West) is chosen by the OXCs 48 at adjacent nodes on each side of the failed link (nodes 58 and 64). The 1+1 protect access port 55 then forwards, via a protect channel (P), the working optical signals which are

transported by the OXCs 38 and 44 via the diverse protect path P(West). The OXCs 48 in nodes 58 and 64 monitor the working optical signals to determine if the link has recovered. If it has, the working path 53 and the working access port 57 may again be utilized and the protect channel (P) is made available.

An optical pass through of the optical signals may be configured between any transit nodes (such as node 62) in the optical ring allowing the signals to flow directly between nodes 58 and 64. As such, a restoration path for the working signals is made available.

When the working traffic in Fig.'s 5, 6, 8, and 9 is rerouted, it is done more efficiently than with some conventional optical communication systems because the signals do not have to terminate on transit data switches (such as data switch 52 in node 62) as they are transmitted through the network. Additionally, as the OXC's enable line speed switching, transponders effectively regenerate signals as they pass through the node thus eliminating the need for amplification or wavelength conversion.

Fig. 10 depicts a computer 70 (which contains a computer program) that comprises a processor 72 and memory 74. The computer 70 may be a personal computer or laptop, the OXC's 18, 28, and 48, the data switches 20, 32, and 52, the WDM coupler 22, the optical amplifier 24, the transponder 26, the regenerator and/or any device that can send and receive optical information. Alternatively, the computer 70 may be representative of several different elements in the systems 10, 40 and 60. The processor 72 may be a central processing unit, digital signal processor, microprocessor, microcontroller, microcomputer, and/or any device that manipulates digital information based on programming instructions. The memory 74 may be read-only memory, random access memory, flash memory and/or any device that stores digital information. The memory 70 is coupled to the processor 72 and stores programming instructions that, when read by the processor, cause the processor to perform certain processing operations.

Fig. 11 describes a method for transmitting an optical signal that may be implemented by the computer 70 of Fig. 8. The method begins at step 80 where optical signals are received by a splitter at a high speed rate via a working path, where the optical signals are short reach optical signals and originate from at least one working

access port on the data switch. At step 82, the splitter forwards the optical signals to the short reach side of a wavelength translation device via the working channel on a primary working path.

At decision 84, a check is performed to determine if extra optical signals are available. If they are, the OXC receives the extra optical signals via a secondary working path at step 86 and transports the extra optical signals via a protect path, wherein the protect path is unused, at step 88.

At decision 90, a check is performed to determine if an equipment failure has occurred. This check may be performed after step 82 and/or 88. If it has, the OXC disconnects the secondary working path transporting the extra optical signals at step 92 and deletes from the protect path, the extra optical signals at step 94. At step 96, the splitter forwards, via a protect channel, the working optical signals and, at step 98, the OXC transports the working optical signals via the protect path.

At decision 100, a check is performed to determine if a line failure has occurred. This check may be performed after step 82, 88 and/or after step 98. If it has, the OXC disconnects the secondary working path transporting the extra optical signals at step 102 and deletes from a diverse protect path, the extra optical signals at step 104. At step 106, the splitter forwards, via a protect channel, the working optical signals and, at step 108, the OXC transports the working optical signals via the diverse protect path.

At decision 84, 90, and/or 100, if the checks are negative, the method proceeds to step 80.

After steps 98 and 108, a check is made at decision 110 to determine if the failure (equipment and/or line) has recovered. If it has, the method proceeds to step 80. If the equipment failure and/or the line failure have not recovered, the method respectively proceeds to steps 96 and 106 where the splitter would continue to forward the working optical signals.

Fig. 12 describes another method for transmitting an optical signal that may be implemented by the computer 70 of Fig. 8. The method begins at step 120 where optical signals are received by a short reach side of a wavelength translation device via a working channel on a working path, where the optical signals are short reach

optical signals and originate from at least one 1+1 working access port on a data switch.

At decision 122, a check is performed to determine if extra optical signals are available. If they are, the OXC receives the extra optical signals via a 1+1 protect access port on the data switch at step 124 and/or via a working access port at step 126, and transports the extra optical signals via a protect path, wherein the protect path is unused, at step 128.

At decision 130, a check is performed to determine if an equipment failure has occurred. This check may be performed after step 120 and/or after step 128. If it has, the OXC disconnects the working access port transporting the extra optical signals at step 132 and deletes from the protect path, the extra optical signals at step 134. At step 136, the 1+1 protect access port forwards, via a protect channel, the working optical signals and, at step 138, the OXC transports the working optical signals via the protect path.

At decision 140, a check is performed to determine if a line failure has occurred. This check may be performed after step 82, 88 and/or 98. If it has, the OXC disconnects the working access port transporting the extra optical signals at step 142 and deletes from a diverse protect path, the extra optical signals at step 144. At step 146, the 1+1 protect access port forwards, via a protect channel, the working optical signals and, at step 148, the OXC transports the working optical signals via the diverse protect path.

At decision 122, 130, and/or 140, if the checks are negative, the method proceeds to step 120.

After steps 138 and 148, a check is made at decision 150 to determine if the failure (equipment and/or line) has recovered. If it has, the method proceeds to step 120. If the equipment failure and/or the line failure have not recovered, the method respectively proceeds to steps 136 and 146 where the 1+1 protect access port would continue to forward the working optical signals.

The present invention thus enjoys several advantages. For example, the data switch includes high speed ports that allow traffic of coarse granularity to enter an optical ring without having to be multiplexed. Since extra optical signals may be transported throughout the disclosed networks, the networks' capacity is increased as the

optical signals and the extra optical signals may be concurrently transported and processed resulting in greater traffic utilization. Also, the use of a splitter in a network of the present invention provides many advantages because the splitter acts in a similar manner to a 1+1 port when optical signals are sent to the splitter via a 0:1 (or working) access port on a data switch. This allows the splitter to receive a working signal and transport it via a working channel or a protect channel. Further, the use of 0:1 (or working) access ports, in addition to 1+1 ports on a data switch of the present invention, provides additional advantages because the data switch (which may contain a splitter) has the ability to provide working optical signals via the 1+1 ports and provide extra traffic via the working access ports. Also, the transponder maps a short reach optical signal into a long reach transport and DWDM ready signal. By utilizing the transponder, wavelength detection schemes at regeneration sites are eliminated because the correct signal is always being transmitted for a particular route. Thus, the wavelengths would always be traveling in the proper direction without having to utilize conventional wavelength detectors. As such, wavelength contingency does not occur and the signals do not incur significant power loss as they transit through the optical switching fabric. Further, by placing the OXC switches on the short reach side of the transponders, the impact of the optical switching fabric unavailability is removed from the transmission link budget, since only the protection traffic is terminated on the OXC. Still further, the optical ring can be easily unbalanced by utilizing a different number of working channels between each node. As such, the amount of transmit and receive equipment is reduced.

It is understood that variations may be made in the foregoing without departing from the scope of the present invention. For example, any number and combination of entities such as optical rings, nodes, OXC's, splitters, transponders, WDM couplers, optical amplifiers, regenerators, working access ports, 1+1 working access ports, and 1+1 protect access ports may be used with the present system. Further, in order to improve signal quality, electrical regeneration devices may be used with the present system. Additionally, any number and combination of these entities may be

contained in or out of the nodes. Still further, unbalanced rings may be utilized in a system containing shared protection fiber.

It is understood that other modifications, changes and substitutions are intended in the foregoing disclosure and in some instances some features of the disclosure will be employed without corresponding use of other features. Accordingly, it is appropriate that the appended claims be construed broadly and in a manner consistent with the scope of the disclosure.

WHAT IS CLAIMED IS:

1. A method for transmitting and restoring optical signals in an optical ring, wherein the optical ring comprises a plurality of nodes, each node comprising an optical cross connect switching fabric coupled to a data switch, wherein the optical cross connect switching fabric is further coupled to a short reach side of at least one wavelength translation device, wherein a long reach side of the at least one wavelength translation device is coupled to at least one dense wave division multiplex coupler, and wherein each node comprises at least one working channel for transporting the optical signals, the method comprising the steps of:

receiving, by a splitter, the optical signals at a high speed rate via a working path, wherein the optical signals are short reach optical signals and originate from at least one working access port on the data switch, wherein the splitter is coupled between the data switch and the optical cross connect switching fabric, and wherein the splitter is further coupled between the data switch and the at least one wavelength translation device;

forwarding, by the splitter, the optical signals to the short reach side of the wavelength translation device via the working channel on a primary working path; and

if extra optical signals are available, wherein the extra optical signals are unprotected and un-restored low priority signals, performing at least one of the following steps from the group consisting of:

receiving, by the optical cross connect switching fabric, the extra optical signals via a secondary working path; and

transporting, by the optical cross connect switching fabric, the extra optical signals via a protect path, wherein the protect path is unused.

2. The method of claim 1 further comprising:

if an equipment failure occurs, performing at least one of the following steps from the group consisting of:

disconnecting, by the optical cross connect switching fabric, the secondary working path transporting the extra optical signals;

deleting, from the protect path, the extra optical signals;

forwarding, by the splitter via a protect channel, the working optical signals; and

transporting, by the optical cross connect switching fabric, the working optical signals via the protect path.

3. The method of claim 1 further comprising:

if a line failure occurs, performing at least one of the following steps from the group consisting of:

disconnecting, by the optical cross connect switching fabric, the secondary working path transporting the extra optical signals;

deleting, from a diverse protect path, the extra optical signals;

forwarding, by the splitter via a protect channel, the working optical signals; and

transporting, by the optical cross connect switching fabric, the working optical signals via the diverse protect path.

4. A system for transmitting and restoring optical signals in an optical ring, wherein the optical ring comprises a plurality of nodes, each node comprising an optical cross connect switching fabric coupled to a data switch, wherein the optical cross connect switching fabric is further coupled to a short reach side of at least one wavelength translation device, wherein a long reach side of the at least one wavelength translation device is coupled to at least one dense wave division multiplex coupler, and wherein each node comprises at least one working channel for transporting the optical signals, the system comprises:

means for receiving, by a splitter, the optical signals at a high speed rate via a working path, wherein the optical signals are short reach optical signals and originate from at least one working access port on the data switch, wherein the splitter is coupled between the data switch and the optical cross connect switching fabric, and wherein the splitter is further coupled between the data switch and the wavelength translation device;

means for forwarding, by the splitter, the optical signals to the short reach side of the wavelength translation device via the working channel on a primary working path; and

means for either receiving the extra optical signals via a secondary working path, or transporting the extra optical signals via an unused protect path, if extra optical signals are available.

5. The system of claim 4 further comprising at least one from the group consisting of:

means for disconnecting, by the optical cross connect switching fabric, the secondary working path transporting the extra optical signals;

means for deleting, from the protect path, the extra optical signals;

means for forwarding, by the splitter via a protect channel, the working optical signals; and

means for transporting, by the optical cross connect switching fabric, the working optical signals via the protect path.

6. The system of claim 4 further comprising at least one from the group consisting of:

means for disconnecting, by the optical cross connect switching fabric, the secondary working path transporting the extra optical signals;

means for deleting, from a diverse protect path, the extra optical signals;

means for forwarding, by the splitter via a protect channel, the working optical signals; and

means for transporting, by the optical cross connect switching fabric, the working optical signals via the diverse protect path.

7. A method for transmitting and restoring optical signals in an optical ring, wherein the optical ring comprises a plurality of nodes, each node comprising an optical cross connect switching fabric coupled to a data switch, wherein the optical cross connect switching fabric and the data switch are further coupled to a short reach side of at least one wavelength translation device, wherein a long reach side of the at least one wavelength translation device is coupled to at least one dense wave division multiplex coupler, and wherein the optical cross connect switching fabric and the data switch include at least

one protect channel and at least one working channel for transporting the optical signals, the method comprising the steps of:

receiving, by the short reach side of the wavelength translation device, the optical signals at a high speed rate via the working channel on a working path, wherein the optical signals are short reach optical signals and originate from at least one 1+1 working access port on the data switch;

if extra optical signals are available, wherein the extra optical signals are unprotected and un-restored low priority signals, performing at least one of the following steps from the group consisting of:

receiving, by the optical cross connect switching fabric, the extra optical signals via at least one 1+1 protect access port on the data switch;

receiving, by the optical cross connect switching fabric, the extra optical signals via at least one working access port on the data switch; and

transporting, by the optical cross connect switching fabric, the extra optical signals via a protect path, wherein the protect path is unused.

8. The method of claim 7 further comprising:

if an equipment failure occurs, performing at least one of the following steps from the group consisting of:

disconnecting, by the optical cross connect switching fabric, the at least one working access port transporting the extra optical signals;

deleting, from the protect path, the extra optical signals;

forwarding, by the 1+1 protect access port, the working optical signals; and

transporting, by the optical cross connect switching fabric, the working optical signals via the protect path.

9. The method of claim 7 further comprising:

if a line failure occurs, performing at least one of the following steps from the group consisting of:

disconnecting, by the optical cross connect switching fabric, the at least one working access port transporting the extra optical signals;

deleting, from a diverse protect path, the extra optical signals;

forwarding, by the 1+1 protect access port, the working optical signals; and

transporting, by the optical cross connect switching fabric, the working optical signals via the diverse protect path.

10. A system for transmitting and restoring optical signals in an optical ring, wherein the optical ring comprises a plurality of nodes, each node comprising an optical cross connect switching fabric coupled to a data switch, wherein the optical cross connect switching fabric and the data switch are further coupled to a short reach side of at least one wavelength translation device, wherein a long reach side of the at least one wavelength translation device is coupled to a dense wave division multiplex coupler, and wherein the optical cross connect switching fabric and the data switch include at least one protect channel and at least one working channel for transporting the optical signals, the system comprises:

means for receiving, by the short reach side of the wavelength translation device, the optical signals at a high speed rate via the working channel on a working path, wherein the optical signals are short reach optical signals and originate from at least one 1+1 working access port on the data switch;

means for receiving, by the optical cross connect switching fabric, the extra optical signals via at least one 1+1 protect access port or one working access port on the data switch if extra unprotected and un-restored low priority optical signals are available; and

means for transporting, by the optical cross connect switching fabric, the extra optical signals via a protect path if extra unprotected and un-restored low priority optical signals are available.

11. The system of claim 10 further comprising at least one from the group consisting of:

means for disconnecting, by the optical cross connect switching fabric, the at least one working access port transporting the extra optical signals if an equipment failure occurs;

means for deleting, from the protect path, the extra optical signals;

means for forwarding, by the 1+1 protect access port, the working optical signals; and

means for transporting, by the optical cross connect switching fabric, the working optical signals via the protect path.

12. The system of claim 10 further comprising at least one of the following capabilities from the group consisting of:

means for disconnecting, by the optical cross connect switching fabric, the at least one working access port transporting the extra optical signals;

means for deleting, from a diverse protect path, the extra optical signals;

means for forwarding, by the 1+1 protect access port, the working optical signals; and

means for transporting, by the optical cross connect switching fabric, the working optical signals via the diverse protect path.

13. A computer program for use in an optical communication network, the program comprising instructions for:

receiving, by a splitter, optical signals at a high speed rate via a working path, wherein the optical signals are short reach optical signals and originate from at least one working access port on a data switch, wherein the splitter is coupled between the data switch and an optical cross connect switching fabric, and wherein the splitter is further coupled between the data switch and a wavelength translation device;

forwarding, by the splitter, the optical signals to a short reach side of the wavelength translation device via the working channel on a primary working path; and

if extra optical signals are available, wherein the extra optical signals are unprotected and un-restored low priority signals,

performing at least one of the following steps from the group consisting of:

receiving, by the optical cross connect switching fabric, the extra optical signals via a secondary working path; and

transporting, by the optical cross connect switching fabric, the extra optical signals via a protect path, wherein the protect path is unused.

14. The computer program of claim 13 further comprising instructions for:

if an equipment failure occurs, performing at least one of the following steps from the group consisting of:

disconnecting, by the optical cross connect switching fabric, the secondary working path transporting the extra optical signals;

deleting, from the protect path, the extra optical signals;

forwarding, by the splitter, the working optical signals; and

transporting, by the optical cross connect switching fabric, the working optical signals via the protect path.

15. The computer program of claim 13 further comprising instructions for:

if a line failure occurs, performing at least one of the following steps from the group consisting of:

disconnecting, by the optical cross connect switching fabric, the secondary working path transporting the extra optical signals;

deleting, from a diverse protect path, the extra optical signals;

forwarding, by the splitter, the working optical signals; and

transporting, by the optical cross connect switching fabric, the working optical signals via the diverse protect path.

16. A computer program for use in an optical communication network, the program comprising instructions for:

receiving, by a short reach side of a wavelength translation device, optical signals at a high speed rate via a working channel on a working path, wherein the optical signals are short reach optical signals and originate from at least one 1+1 working access port on a data switch;

if extra optical signals are available, wherein the extra optical signals are unprotected and un-restored low priority signals, performing at least one of the following steps from the group consisting of:

receiving, by an optical cross connect switching fabric, the extra optical signals via at least one 1+1 protect access port on the data switch;

receiving, by the optical cross connect switching fabric, the extra optical signals via at least one working access port on the data switch; and

transporting, by the optical cross connect switching fabric, the extra optical signals via a protect path.

17. The computer program of claim 16 further comprising instructions for:

if an equipment failure occurs, performing at least one of the following steps from the group consisting of:

disconnecting, by the optical cross connect switching fabric, the at least one working access port transporting the extra optical signals;

deleting, from the protect path, the extra optical signals;

forwarding, by the 1+1 protect access port, the working optical signals; and

transporting, by the optical cross connect switching fabric, the working optical signals via the protect path.

18. The computer program of claim 16 further comprising instructions for:

if a line failure occurs, performing at least one of the following steps from the group consisting of:

disconnecting, by the optical cross connect switching fabric, the at least one working access port transporting the extra optical signals;

deleting, from a diverse protect path, the extra optical signals;

forwarding, by the 1+1 protect access port, the working optical signals; and

transporting, by the optical cross connect switching fabric, the working optical signals via the diverse protect path.

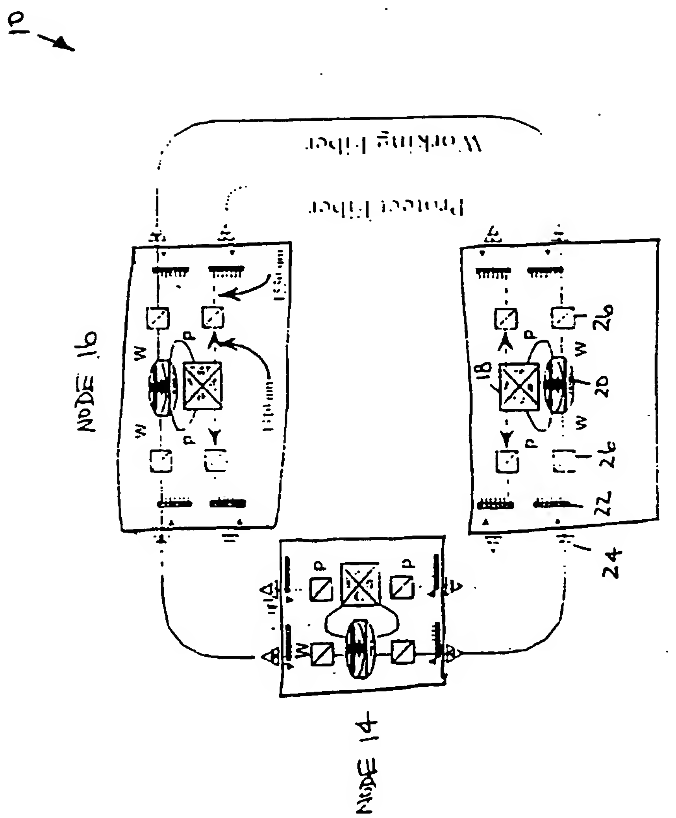

Fig. 1

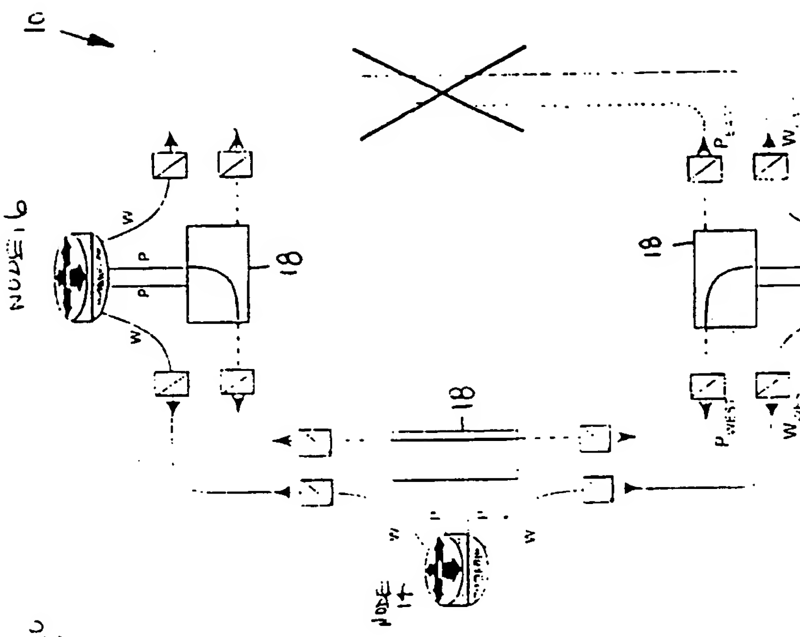
10
NODE 16
18
18
NODE 12
P EAST
W EAST
P WEST
W WEST
18
NODE 14

Fig. 3

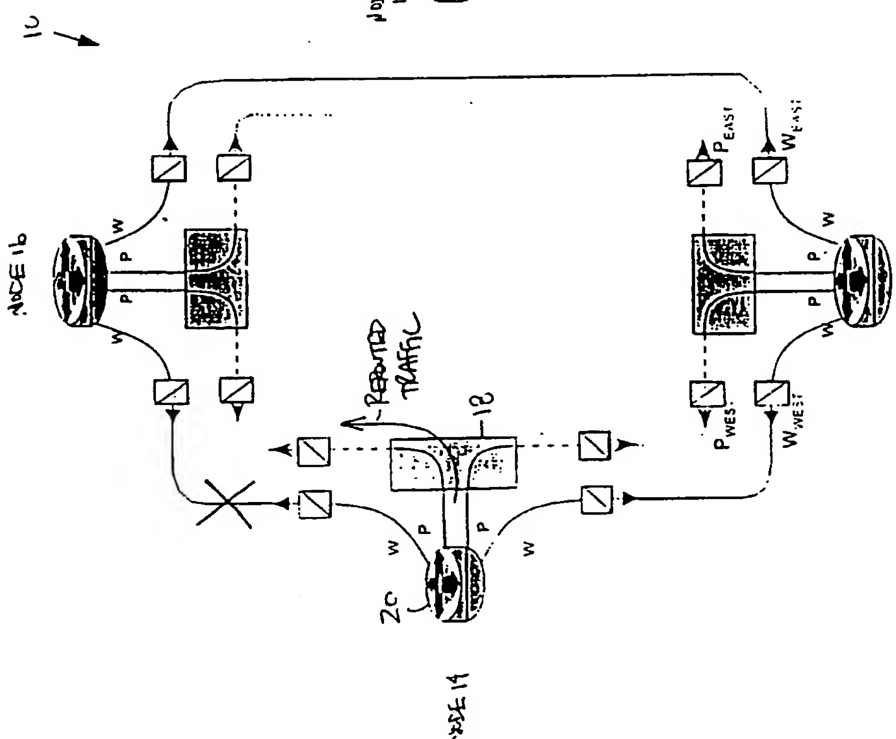
10
NODE 16
NODE 12
P EAST
W EAST
P WEST
W WEST
REROUTED TRAFFIC
12
20
NODE 14

Fig. 2

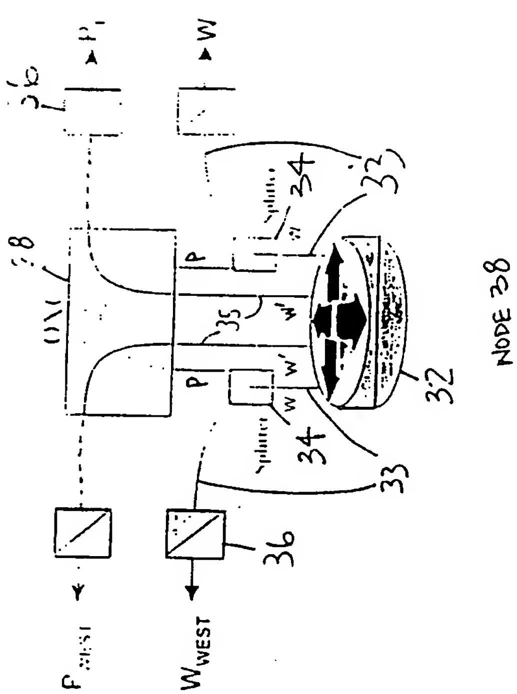

Fig. 4

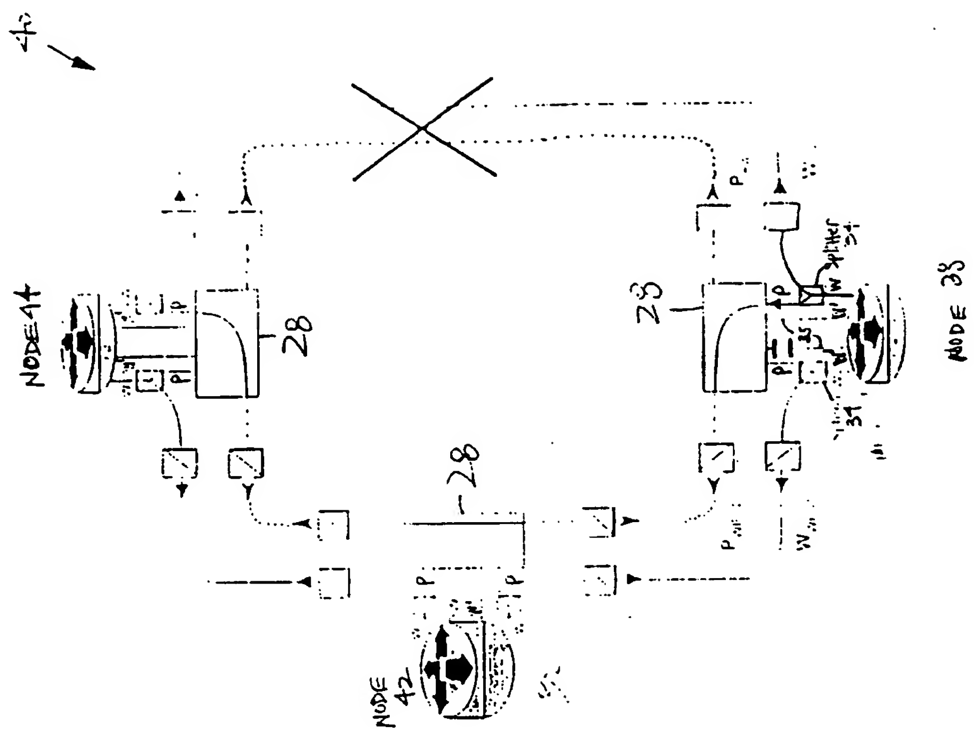
NODE 44
28
28
NODE 42
28
NODE 38
splitter
34
34
35

Fig. 6

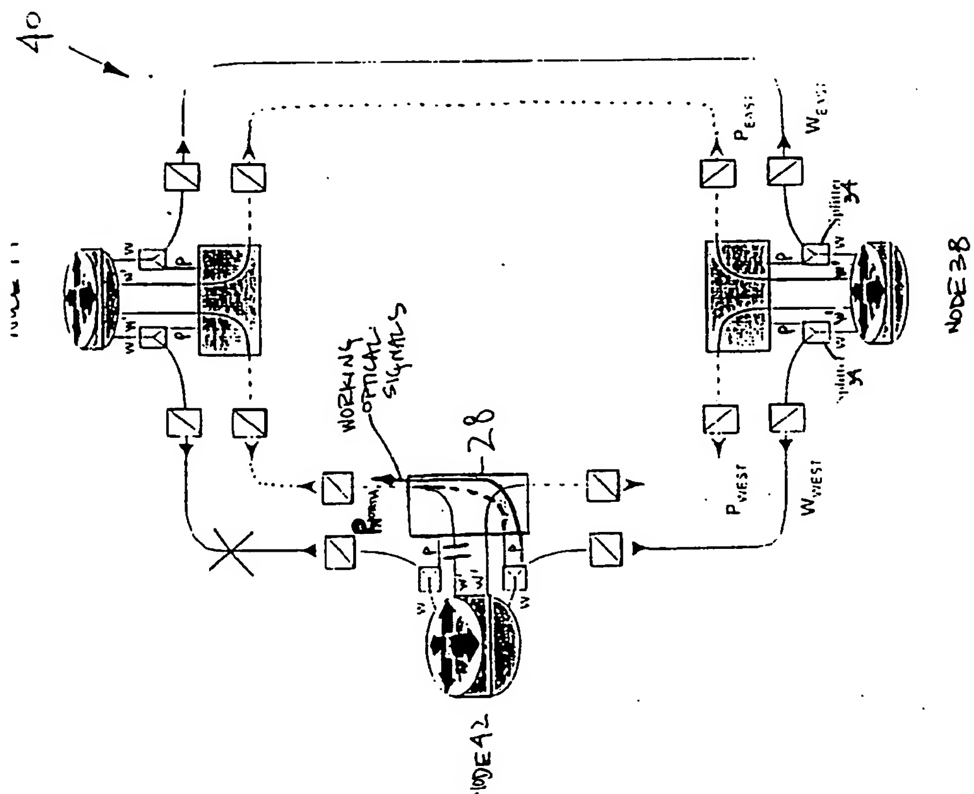
40
NODE 38
NODE 42
28
WORKING OPTICAL SIGNALS
P_{EAST}
W_{EAST}
P_{WEST}
W_{WEST}
34
34

Fig. 5

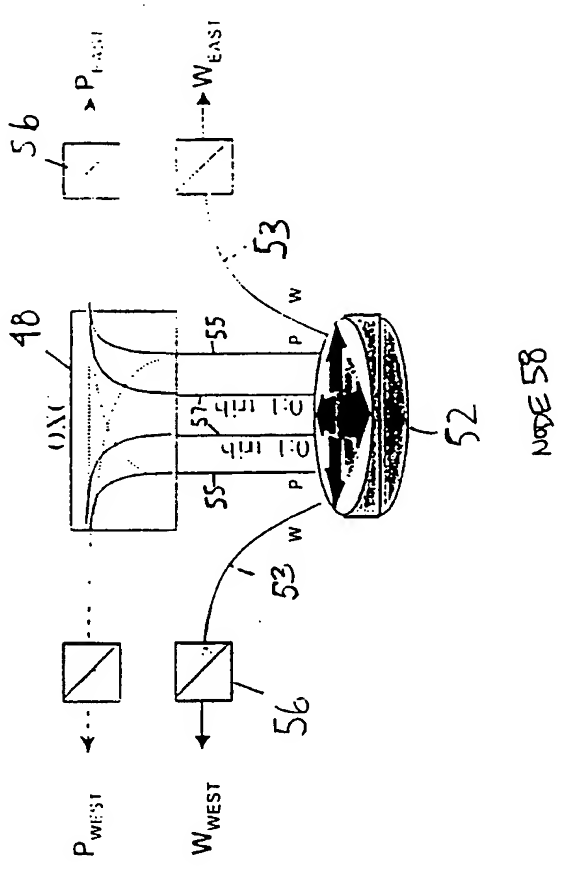
56
P_{EAST}
W_{EAST}
53
48
OXC
55
57
0:1 nib
0:1 nib
p
w
52
55
53
56
P_{WEST}
W_{WEST}
NODE 58

Fig. 7

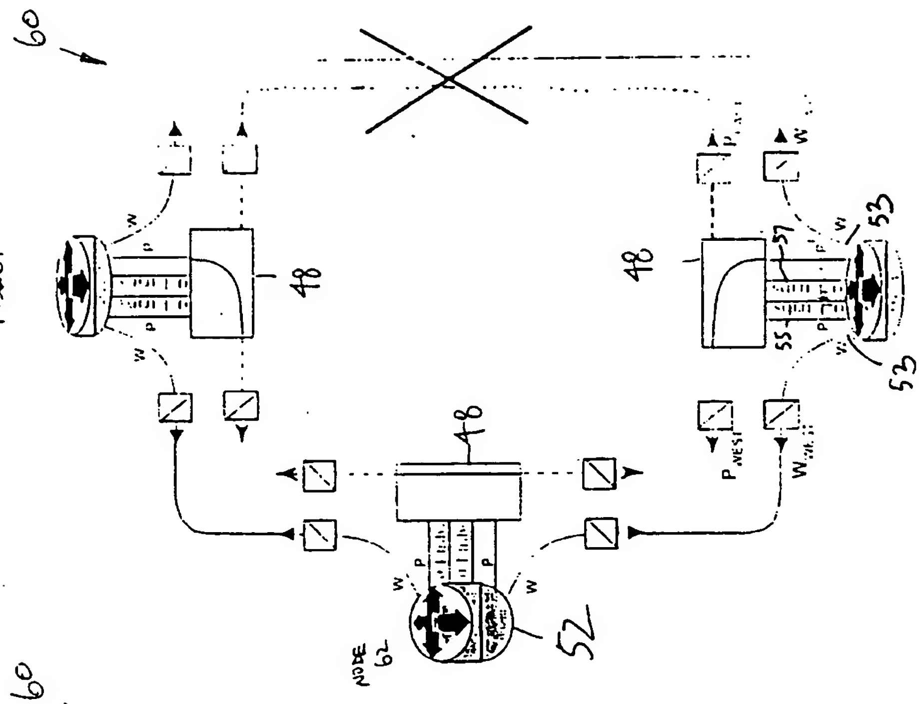
60
NODE 64
48
NODE 58
53
57
55
NODE 62
52

Fig. 9

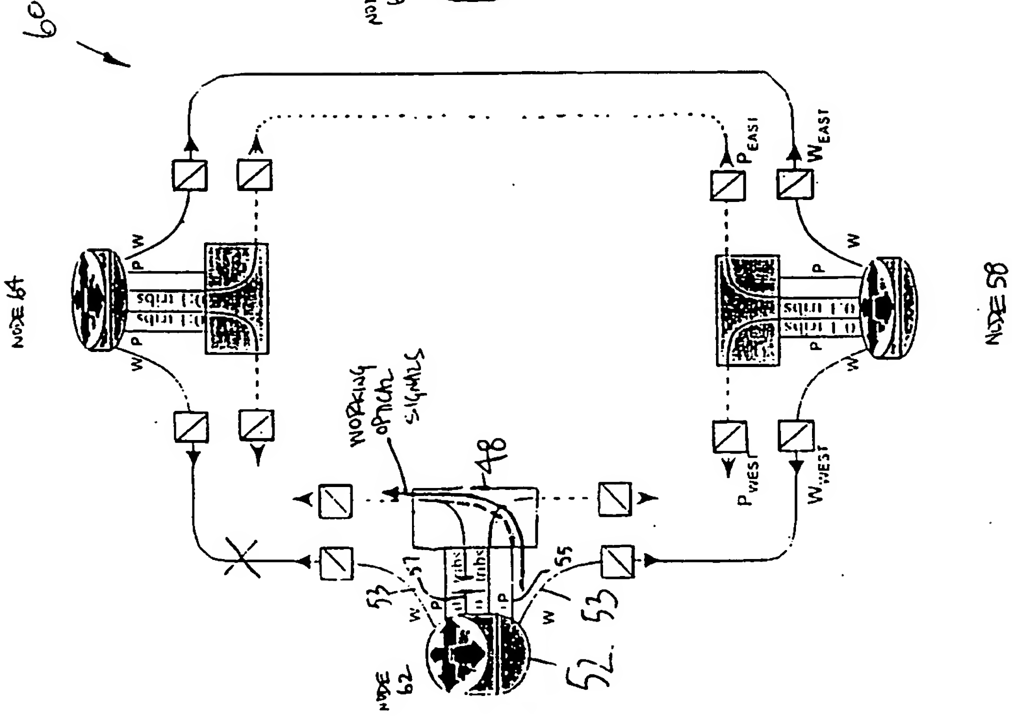
60
NODE 64
NODE 58
P EAST
W EAST
P WEST
W WEST
WORKING OPTICAL SIGNALS
48
NODE 62
52
53
55
57

Fig. 8

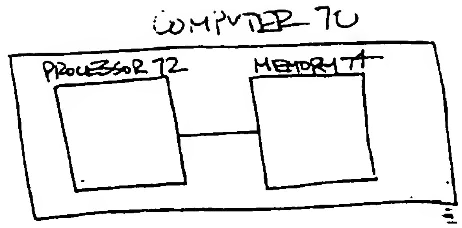

Fig. 10

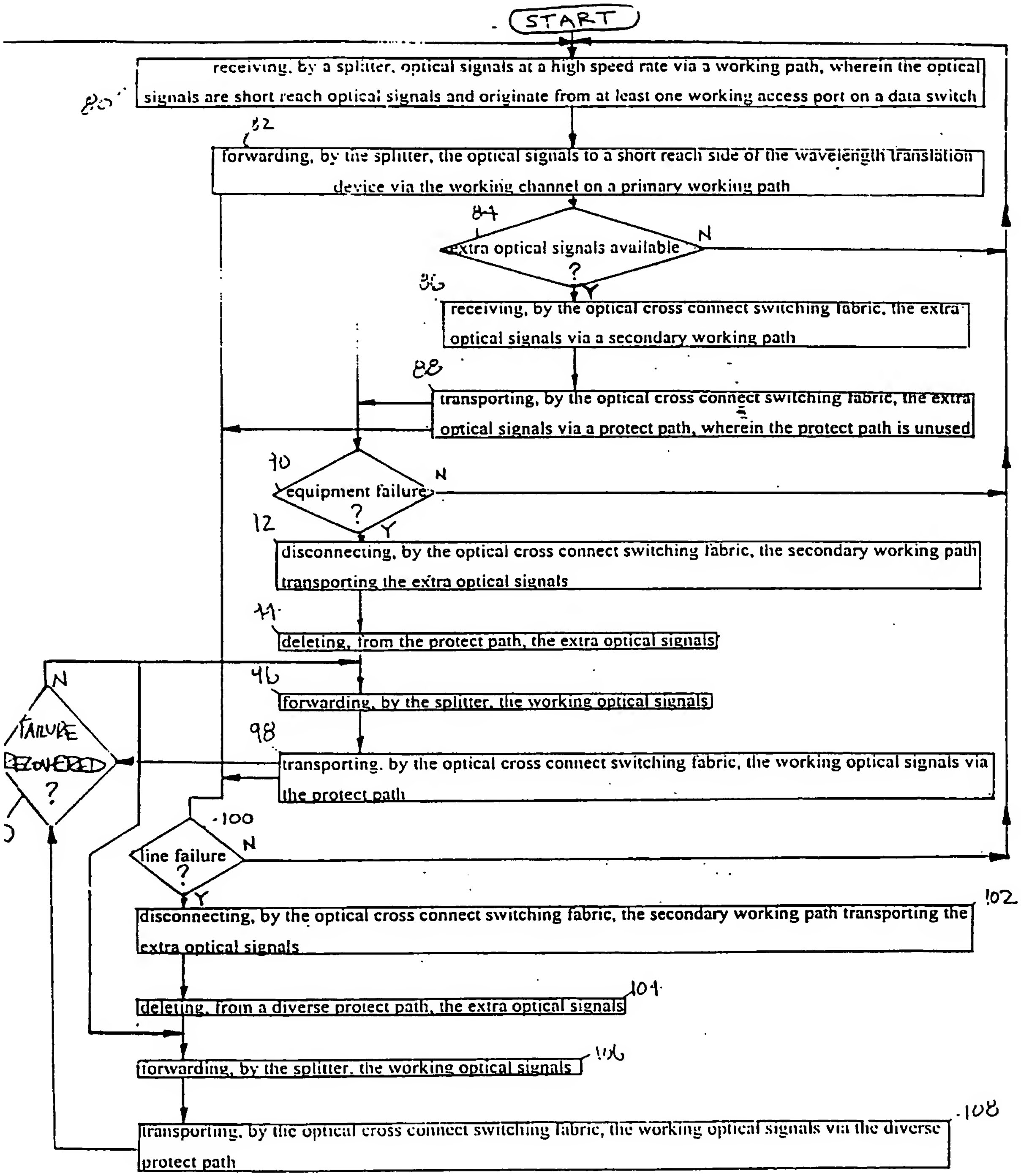
START
receiving, by a splitter, optical signals at a high speed rate via a working path, wherein the optical signals are short reach optical signals and originate from at least one working access port on a data switch
80
82
forwarding, by the splitter, the optical signals to a short reach side of the wavelength translation device via the working channel on a primary working path
84
extra optical signals available ?
N
Y
86
receiving, by the optical cross connect switching fabric, the extra optical signals via a secondary working path
88
transporting, by the optical cross connect switching fabric, the extra optical signals via a protect path, wherein the protect path is unused
90
equipment failure ?
N
Y
92
disconnecting, by the optical cross connect switching fabric, the secondary working path transporting the extra optical signals
94
deleting, from the protect path, the extra optical signals
96
forwarding, by the splitter, the working optical signals
98
transporting, by the optical cross connect switching fabric, the working optical signals via the protect path
FAILURE RECOVERED ?
N
100
line failure ?
N
Y
102
disconnecting, by the optical cross connect switching fabric, the secondary working path transporting the extra optical signals
104
deleting, from a diverse protect path, the extra optical signals
106
forwarding, by the splitter, the working optical signals
108
transporting, by the optical cross connect switching fabric, the working optical signals via the diverse protect path

Fig. 11

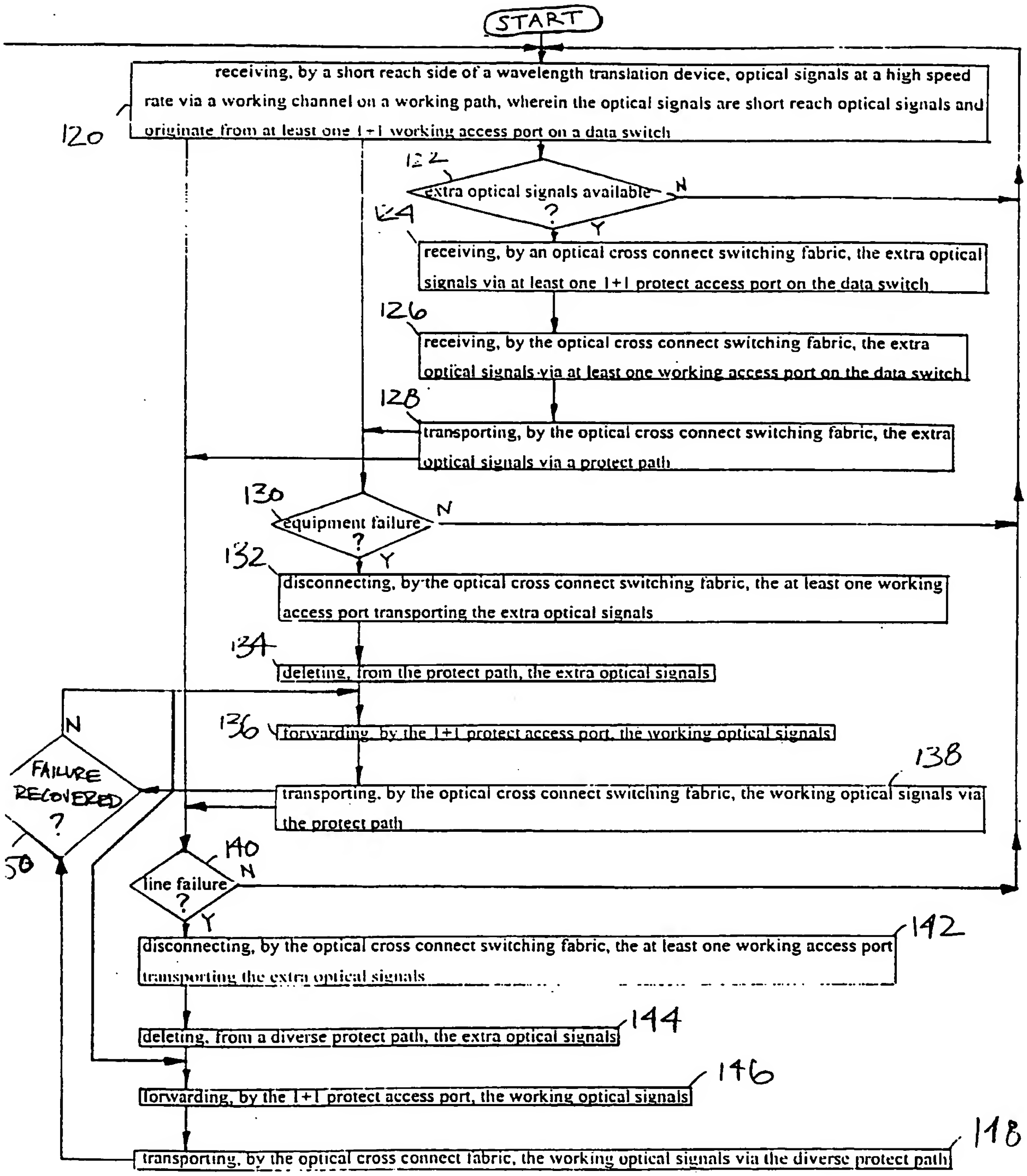
START
receiving, by a short reach side of a wavelength translation device, optical signals at a high speed rate via a working channel on a working path, wherein the optical signals are short reach optical signals and originate from at least one 1+1 working access port on a data switch
120
122
extra optical signals available ?
N
Y
124
receiving, by an optical cross connect switching fabric, the extra optical signals via at least one 1+1 protect access port on the data switch
126
receiving, by the optical cross connect switching fabric, the extra optical signals via at least one working access port on the data switch
128
transporting, by the optical cross connect switching fabric, the extra optical signals via a protect path
130
equipment failure ?
N
Y
132
disconnecting, by the optical cross connect switching fabric, the at least one working access port transporting the extra optical signals
134
deleting, from the protect path, the extra optical signals
136
forwarding, by the 1+1 protect access port, the working optical signals
138
transporting, by the optical cross connect switching fabric, the working optical signals via the protect path
N
FAILURE RECOVERED ?
150
140
line failure ?
N
Y
142
disconnecting, by the optical cross connect switching fabric, the at least one working access port transporting the extra optical signals
144
deleting, from a diverse protect path, the extra optical signals
146
forwarding, by the 1+1 protect access port, the working optical signals
148
transporting, by the optical cross connect fabric, the working optical signals via the diverse protect path

Fig. 12

INTERNATIONAL SEARCH REPORT

Inte   onal Application No
PCT/US 00/41278

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04J14/02 H04Q11/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04J H04Q H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 0 752 794 A (FUJITSU LTD) 8 January 1997 (1997-01-08) column 1, line 7 - line 8 column 3, line 31 -column 7, line 6 column 8, line 19 -column 10, line 16; figure 1 column 12, line 11 - line 55; figures 3,4 column 13, line 16 -column 14, line 14; figures 6,7 column 15, line 14 -column 16, line 18; figure 10 column 17, line 27 - line 51; figure 12 column 20, line 18 - line 27; figure 15 column 21, line 18 - line 35; figure 18 column 21, line 50 -column 22, line 4; figure 20 column 22, line 42 -column 23, line 30; figure 23 --- -/--	1-18

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 March 2001	02/04/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Roldán Andrade, J

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Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	RAMASWAMI, R. ; SIVARAJAN K. N.: "OPTICAL NETWORKS: A PRACTICAL PERSPECTIVE" 1998 , MORGAN KAUFMANN , SAN FRANCISCO, USA XP002162973 239820 page 430, paragraph 2 -page 458, paragraph 3; figures 10.2,10.4-10.9,10.11-10.16,10.20	1-18
P,X	EP 1 028 550 A (KDD CORP ;MITSUBISHI ELECTRIC CORP (JP)) 16 August 2000 (2000-08-16) column 1, line 5 - line 9 column 5, line 44 -column 6, line 15 column 10, line 50 -column 18, line 16; figures 4-6 column 21, line 35 -column 22, line 58; figures 11,12	1-18
A	EP 0 928 082 A (PIRELLI CAVI E SISTEMI SPA) 7 July 1999 (1999-07-07) column 1, line 5 - line 9 column 2, line 29 - line 44 column 4, line 19 -column 8, line 24; figures 1,2	1-18
A	STERN, T.E. ; BALA, K.: "MULTIWAVELENGTH OPTICAL NETWORKS: A LAYERED APPROACH" May 1999 (1999-05) , ADDISON-WESLEY , READING, MASSACHUSETTS, US XP002162842 240050 page 607, paragraph 1 -page 654, paragraph 4; figures 8.1-8.30 page 662, paragraph 5 -page 664, paragraph 1; figure 9.1	1-18

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

Inte. .onal Application No
PCT/US 00/41278

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